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RESEARCH PAPER

Transpiration surface reduction of Kousa Dogwood trees during serious water imbalance

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Abstract: The response of Kousa dogwood (*Cornus kousa* Buerg.) to extreme stresses was investigated by RGB image analysis in the hot, dry and windy summer in 2007 in Yamaguch, Japan. Results show that tip and margin leaf scorch was observed on many Kousa dogwood trees and clearly dark brown defense barrier appeared on scorched leaves. The defense barrier withdrew back from distal to proximal gradually until successful control of scorching, and left a series of unsuccessful defense traces. By responsive analysis of leaf color homogeneity with RGB image analysis method, a sharp logistic equation was obtained for the relative green/luminance (RGL) value of scorched leaves. By the meteorological analysis, the occurrence of dogwood leaf scorch-back was almost synchronous with the aridity peak period. It suggested that during the sudden aridity increment the extreme water stresses induce the defense response of Kousa dogwood tree to shear the excessive transpiration leaf area, and prevent the rest of the trees from further water loss. Image pixel analysis showed that 40.2% leaf area of sampled dogwood trees was reduced through the partial leaf scorch-back by the end of August in 2007. In contrast, only 13.2% leaf area was reduced from the same trees in 2008, for the reason of sufficient precipitation during first half year. In any case, the Kousa dogwood trees indeed reduced their transpiration surface area and appeared a surface reduction pattern differing from those shedding leaves or withering all the aboveground. Based on desiccation process analysis, it is considered that the interaction of the leaf dried back and the self-defense response was the key of the transpiration surface reduction (TSR) of Kousa dogwood during sudden hot and droughty stresses.

Keyword: aridity peak; Kousa dogwood; leaf scorch-back; logistic responsive function; relative G/L; transpiration surface reduction

Introduction

Plants usually live in the contradict processes of capturing large amount of carbon and energy at expense of enormous water. High photosynthesis and carbohydrate production per land area need additional leaf areas, which imply more water and nutrition consumption. Most of water absorbed from soil is lost by plant transpiration and less 5% is used in metabolism and growth. Therefore transpiration has ever been regarded as an unavoidable evil since it causes water deficit and injury by dehydration (Kramer 1983). Acting as transpiration cooler to avoid leaf temperature over rise, causing the ascent of sap and increasing the absorption of minerals, transpiration is also considered to be beneficial (Clements 1934). Plant tissues dissipate heat by three main processes, emission of long-wave radiation, convection of heat, and transpiration of water. Of which transpiration tends to be the most effective process of heat dissipation for plant tissues, particularly at the sunny midday. High plant temperatures (>40°C) are almost invariably associated with the cessation of transpiring cooling, following stomata closure in response to drought (Fitter et al. 2002). Therefore transpiration-cooling failure during a serious drought stress seems lethal to plants. In addition, increase in temperature tends to cause an increase in the rate of transpiration through its effect on saturation water vapor density (Fitter et al. 2002). Under these conditions, excessive leaf area usually causes imbalance of energy and water so as to be dangerous to their lives. Many plant species respond the unfavorably extreme hot and droughty stress by transpiration surface reduction (TSR) to maintain the water balance of the rest parts. TSR has been considered as a hydro-ecological factor for a long time (Orshan 1954; 1989), as the protective response (LIU et al., 2007) and as an approach of reducing radiation acceptation to maintain the energy balance of plants (Kozlowski 1973). It can be seen in various patterns; for instance, leaf or branch shedding for many deciduous trees even evergreens (Addicott 1973; Rust et al. 2004; Kozilowski 1976) and the death of aboveground for most annuals and grasses etc. (Kozlowski 1973; Bhat et al. 1986). Some tree species respond the unfavorably extreme droughty environment with partial leaf scorch (Yapp 1912; Treshow 1970; Vollenweider et al. 2006; Günthardt-Goerg et al. 2007) since the special leaf structures and adaptive mechanism. This kind of response can be remarked as a process of partial aboveground death. The homogeneity between these trees is shrinking-back of the living parts from distal to proximal to respond the water defi-

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cit and excessive radiation acceptance. Through partially withering leaves, these trees reach the trade-off among water loss, radiation acceptance and CO_2 fixation to survive the extreme hot and droughty environment. Unlike the plants that respond to drought stress as a whole, or tissues and organs evenly changed, many of them showed uneven responses from distal to proximal. As a result, partial transpiration leaf area of these trees was sheared. Many landscape trees including bamboos (*Sasa sp.*), dogwoods (*Cornus sp.*), and Oaks (*Quercus sp.*) even some succulent plant species (Addicott 1982) usually appear similar symptom.

Kousa Dogwood is a well-known landscape tree species with showy flower, and widely cultivated along streets and around houses in Yamaguchi city, Japan. But it often shows leaf scorch affected by drought, after root injury and transplanting shock etc. Similar symptoms appeared on many dogwood trees after affected by dry and hot summer in 2007 in Yamaguchi city. Tip and/or edge leaf scorch occurred on many of dogwood trees, which made the crown of them discoloration in different scales. Gradually drying back of living tissues during unfavorably extreme drought stresses took place, accompanying with the occurrence of clear defense barrier. During the spring and summer in 2008, the gradual scorch-backed leaves were also observed on some transplanting shocked and normal dogwood trees in Yamaguchi. The heterogeneousness of leaf scorch-back and leaf color variation from distal to proximal causes some difficultness to directly measure the scorched leaves. The flexibility of RGB image analysis makes it suitable to measure the leaves differentially. In the present study, the leaf RGB images were equally divided into ten sections from proximal to distal and the "Switch-off" types of threshold responsive functions (Thornley 1976) were used to describe the gradually scorched leaves. The leaf water content was also analyzed by similar differential pattern. The TSR process of the dogwood trees during the abnormal extreme drought events was described quantitatively by using the image pixel analysis and water content measurement of scorched leaves.

Materials and methods

Dogwood trees (7-year-old) with height of 3–4 m were observed to study the leaf scorching response to the extreme drought stresses in the years of 2007 and 2008. Some newly planted dogwood saplings were also observed to research the transplanting shock during the early summer in 2008. All of them were planted around/near a park that is the ancient riverbed and the former athletic track in Yamaguchi city, Japan. Branch dieback occurred on many landscape tree species planted around, including the dogwood trees. On the stems of some dogwood trees, the trace of scale insect parasite was also found. It suggested that improper site condition made the trees sensitive to environmental changes.

The RGB image of leaf scorch-back for these dogwood trees came from leaf scanning with a flat bed scanner (Canon D125u2). Ten leaves were typically sampled from each tree and 60 plants were mechanically sampled in total. Leaf scorch area percentage (*LSAP*), which is the proportion of scorched area to overall leaf area, was determined by image pixel method. It was measured by getting pixels of overall leaf and the green part for each leaf with Photoshop. The LSAP was calculated by Equation (1).

$$LSAP\,(\%) = 100 - \left(\frac{\text{Pixels for green area of leaf}}{\text{Pixels for overall leaf}} \times 100\right) \tag{1}$$

To analyze the characteristics of leaf scorch, the same leaf images in *LSAP* calculation were used to measure the *G/L* value, an index in RGB image analysis (Wang et al. 2008). Before getting RGB pixel data, the images were hand prepared by eraser of Photoshop to remove the background and objects except for the objective leaf. Then leaf images were equally divided into 10 sections from base to tip. The green (*G*) luminance (*L*) values for each section were read from the average histogram value of Photoshop. The *G/L* value of leaves was calculated by the Equation (2).

$$G/L_{leaf} = \frac{\text{green value of the leaf}}{\text{luminance value of the leaf}} \tag{2}$$

By repeated regression test, the relative *G/L* (*RGL*) decreased nonlinearly from proximal to distal and could be modeled by logistic threshold responsive Equation (3) for scorched leaves.

$$RGL\,(n) = \frac{k}{1 + e^{a-rn}} \tag{3}$$

where *RGL* (refer to Equation 4) stands for relative *G/L*. *RGL*(n) is the *RGL* value at n section. Obtained by regression process, *r* is the regression coefficient, *a* is a constant, and *k* is the maximum value that the *RGL* can reach. The character n (=1,2,…,10) is the number of leaf sections.

$$RGL_i = \frac{100 \times (G/L_i - G/L_{\min})}{(G/L_{\max} - G/L_{\min})} \tag{4}$$

where G/L_i is the *G/L* value for *i* section, G/L_{min} is the minimum *G/L* value of all sections, and G/L_{max} is the maximum *G/L* value of all sections.

Leaf water relation was also studied by continually measuring water content before and after scorch-back. Small twigs were cut from selected trees and then taken back to lab with vinyl-bags. The water content (*WC*) for single leaves or leaf sections from newly transplanted saplings and normal growing trees were measured by rapid weighing method with an electronic balance (1/10000 g) at room natural environment. The fresh weight of sampled leaves, or leaf sections was weighed after sampling from field site without delay. After obtained the dried weight of them, the water content was calculated by Equation (5)

$$WC\,\% = \frac{FW - DW}{FW} \times 100\,\% \tag{5}$$

where *FW* is the fresh weight of leaf samples and *DW* is dried weight of them.

In order to find the relation between TSR and the extreme hot and drought event, the daily meteorological data during 2007 and 2008 for Yamaguchi Observatory, 1.2 km from the investigated trees, was obtained from Automated Meteorological Data Acquisition System of Japan, and the first 10 records for maximum or minimum values from 1976 to 2007 as well. The 11th day's aridity index (*AD*11) was calculated by Equation (6) for the meteorological data from April 1st to August 31, in both 2007 and 2008, respectively.

$$AD11_i = \sum_{j=0}^{10} MT_{i+j} \Big/ \sum_{j=0}^{10} PR_{i+j} \tag{6}$$

where i=1,2,…,153 and i=1 on the April 1st. *MT* is the daily maximum temperature and *PR* is daily precipitation.

Results and discussion

TSR of Kousa dogwood after persistent droughty weather in 2007

Visible symptoms of the Kousa dogwood caused by extreme hot and droughty event varied significantly from trees to trees and among leaves (Fig. 1-a). The threshold responsive equation for image *RGL* value of leaves with different scorch area (Fig. 1-a leaf 2, leaf 3 and leaf 4) presented distinct inverse logistic curves (Fig. 1-b. leaf 2, leaf 3, leaf 4). This indicated that the injury did not evenly distribute on the leaves and the scorched area bound from distal to proximal, which is typical scorch-back characters. Carefully observed the scorched leaf, apparent defense barrier existed on the leaf surface and the barrier lines also arranged from distal to proximal catastrophically (Fig. 1-a, Fig. 1-d). The shape of responsive function varied from inverse sigmoid shape to rectangular hyperbola shape (refer to Fig. 1-b) as the scorch became severe. Meanwhile the leaf area was reduced through scorching the part outside the barrier. According to the color analysis of scorched part, only one major defense barrier can be observed on most of the leaves (Fig. 1-c). For seriously injured leaves, two (Fig. 1-d) even three or more defense barriers can be seen. It indicated that the defense barrier withdrew back from distal to proximal gradually until successfully resist scorching and left a series of unsuccessful defense traces (Fig. 1-a, Leaf 3, Leaf 4). The threshold responsive curves for both non-scorched leaf and entirely scorched leaf (Fig. 1-a Leaf 1, Leaf 5) appeared a tendency of straight lines slightly slanted and laid on top and bottom of the coordinate separately (Fig. 1-b), which should be the characteristics of the trees with no scorched leaves and with dead leaves separately.

Most of the leaves, appeared multi defense traces, contained two belts differently colored and separated by two defense barriers (Fig. 1-d). Two scorched periods occurred from the sprouting of the leaves and showed different responsive function curves.

Despite the characteristic of the defense barrier and leaf scorched area varied significantly, the total living area of leaves commonly reduced. Based on the calculation, the image LSAP was about 40% of sampled leaves in total. The first and second phases respectively accounted for 2.7% and 38.6% for all of the sampled trees. Even if the precipitation during the first nine months was coincident about 40% less than that of normal years, the relevance between the leaf scorch of Kousa dogwood trees and less precipitation should be less doubt. It is clear that Kousa dogwood trees manifested a grass-like response to the summer drought in 2007, and showed serious leaf scorch-back under the insufficient water supply. Leaf scorch became serious as the stresses increase and resulted in decreasing the leaf areas of living part, which indirectly decreased the water or precipitation requirement and received less radiant energy for the living parts of entire tree. Meanwhile, the green parts of scorched leaves maintained active status and as the environment became favorable they restored vigorous immediately. In the same city, the green part of scorched leaves of some Japanese blue oak (*Quercus glance* Thunb.) trees hit by typhoon 0613, maintained normal function more than two years was observed.

TSR of some Kousa dogwood during transplanting shock in 2008

After transplantation, the successful survival of trees mostly depends on rapidly establishing the perfect root system. If not, the new sprouting leaves usually dried out or scorched-back under sudden drought environment for the reason of serious water imbalance. Sufficient precipitation, 116% of the normal, during the first half year in 2008 resulted in almost no appearance of leaf scorch symptoms during early summer days in 2008 on the same dogwood trees observed in 2007 (Fig. 2a-1). Only some newly complementarily planted trees showed the gradually leaf scorch symptoms during the sudden temperature increase and persistent no rain in the first days of May (Fig. 2a-2, 2a-3). Leaves from normal growing trees appeared a level curve of *RGL* value in Fig. 2b-1; while under the transplanting shock, the leaves desiccated from tip to base and the uneven appearance from distal to proximal can be seen from Fig. 2a-2. A black shade layer, as described by Whitehead (1963), between dried and non-dried area was observed, and the responsive curve slanted at tail end (Fig. 2b-2). In this situation, although the leaf tip had dried out, the color of it still remained green, which indicated that water loss was too fast to change the chlorophyll. Three days later, the leaf tips became deep gray (Fig. 2a-3) and a typical *RGL* responsive function of inverse logistical curve or scorch symptom occurred (Fig. 2b-3). During the shock, a lot of seriously hit leaves dried out after several days of temperature increase and no rain weather at the beginning of the May in 2008. Soon after, the coming of the Japanese rainy season and about 350 mm monthly precipitation in June promoted the new sprouting of small leaflets with long and narrow tips on the tree. Measured by image pixel method, single leaf area of the new leaves was only 38.6% of that before the shock. After the end of the Japanese rainy season in the beginning of July and about ten

days of persistent drought and hot weather, the remained leaves and small new sprouting leaves scorched-back once again (Fig. 2a-4, 2b-4). Some of them also presented two barriers after two periods of shock (Fig. 2a-5-A, B; 2b-5,). The *RGL* responsive lines showed a similar tendency as the first shock during May.

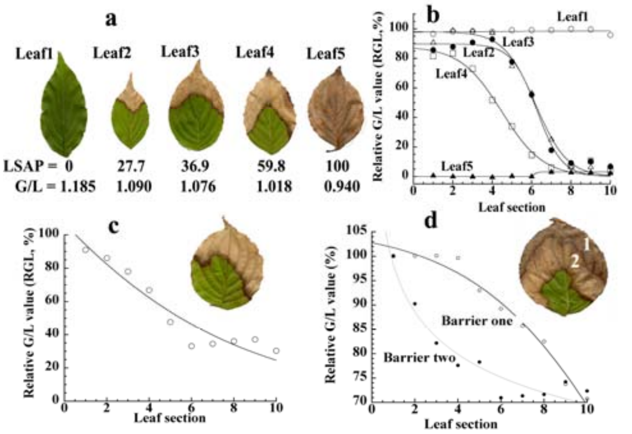

Fig. 1 Variant characteristics of Kousa dogwood leaf scorch from proximal to distal and defense barriers. Fig. 1-a presented five leaves from different trees with different leaf scorch area percentage (LSAP), 0, 27.7, 36.9, 59.8 and 100, respectively. Image *G/L* value ranges from the maximum (1.258) to the minimum (0.744); Fig. 1-b was the responsive curves of relative *G/L* (*RGL*) for these leaves, with the characteristics of typical logistic curves for scorched leaves (Leaf 2, Leaf 3 and Leaf 4), and straight lines for overall green and entire brown leaves (Leaf 1 and Leaf 5); Fig. 1-c showed a leaf with one defense barrier and its *RGL* threshold responsive curve; Fig. 1-d presented a leaf with two barriers constructed in May and August 2007, and related threshold responsive curve of *RGL* value. In addition, the threshold function in Fig. 1-d was established by refilling method or after normally making the second threshold curve, the first one was established by filling the scorched area between the first and second barrier with average green value of the leaf.

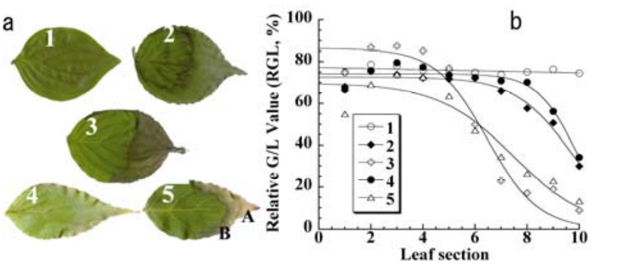

Fig. 2 Different leaf scorch-back of Kousa dogwood during transplanting shock period in 2008; the characteristics of normal leaf (a1), initial scorched leaf (a2, a4), post scorched leaf (a3), scorched leaf with single barrier line (a4) and dual barrier lines (a5-A, B). The threshold responsive curves of relative *G/R* (*RGL*) value of normal leaf (b1), initial scorched leaf (b2, b4), post-scorched leaf (b3), single barrier (b4) and dual barriers (b5). The responsive threshold curves were made by the average values at each point.

Water relation during TSR of Kousa dogwood

Leaf scorch-back of normal Kousa dogwood trees extended a prolonged process. During this process, leaves usually appeared different degrees of scrolling for a long time and maintained lower water content than those on normal growing trees (Fig. 3-a). Although there was a tendency of lower distal to proximal ratio of water content as the hot and droughty conditions persisted (Fig. 3-b), the value of this ratio remained above 1.0 (Fig. 3-b) until a few leaves showed significant leaf scorch-back on a tree during the sudden hot and dry weather (Fig. 4-a). During this period of time, some of the leaves appeared evident tendency of water content variance between leaf tip and base with a regression line of water content slightly down slanted from proximal to distal (Fig. 4-a). But the logistic threshold response curve (Fig. 4-b) could not be seen till serious leaf scorch-back occurred on the tree. It suggests that the ratio of distal to proximal would not significantly change until it reaches the threshold point of water content.

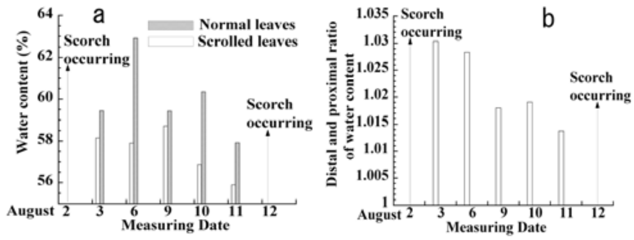

Fig. 3 The variation tendency of water content for normal growing leaves and scrolled leaves (Fig. 3-a) and the water content ratio between distal and proximal of normal Kousa dogwood trees during seriously hot and dry summer weather conditions and at the interval of two times of leaf scorch occurrence (Fig. 3-b). In Fig. 3-b the distal to proximal ratio was the proportion of the water content between distal and proximal part of the leaves that were divided into three parts, distal, middle and proximal. The data in Fig. 3-b was the average value from five trees and ten leaves for each tree.

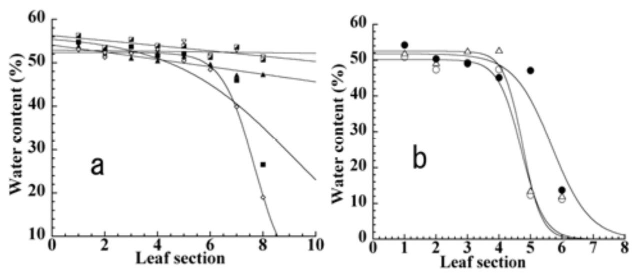

Fig. 4 The variation tendency of water content at the threshold status of leaf scorch-back during the persistently dry and hot summer days in August 2008. It showed the water content for the leaves before the serious scorch-back (Fig. 4-a), in which it contained early stage of scorched leaves (◊–◊, ■–■), seriously wilted leaf (▲–▲) and wilted leaves (∇–∇, ◪–◪). After the significant scorch-back occurred the significant defense barrier appeared (Fig. 4-b), which contained the leaves with dual defense barriers (○–○, Δ–Δ) and single defense barrier (●–●). In this figure leaves were hoof-shapely cut into seven or eight (according to the leaf size) sections from proximal to distal to reflect the water gradient.

According to a large amount of measurement, Kousa dogwood is characterized by higher leaf water loss speed than many other deciduous or evergreen tree species in detached condition. However, proper interconnection of leaf venation is sufficient to counteract this shortcoming. It is observed that the main vein cutting from leaf base cannot suffice to result in leaf water imbalance of attached Kousa dogwood leaves. The local injury to the leaf vascular system does not necessarily cause the water transport obstacle (Kramer 1983). Therefore, the whole sectional barrier is necessary to interrupt the persistent water loss during the extreme water imbalance. According to observation, the defense barrier usually appeared during night, which suggests it is a response to water stress that cannot be completed without adequate water (Kozlowski 1976). Some transplanted dogwood trees did not appeared the barrier until a rainy day. In some situations, not only one barrier but also two even more unsuccessful defense traces can be seen on the same leaf (Fig. 1a-leaf 3, leaf 4). It seems that the establishment of the defense barrier was an active protection process. This means that under the serious tension of enlarged water gradient, leaves responded to the summer drought by actively shearing the terminal part to protect main body from further water loss and reduce the transpiration.

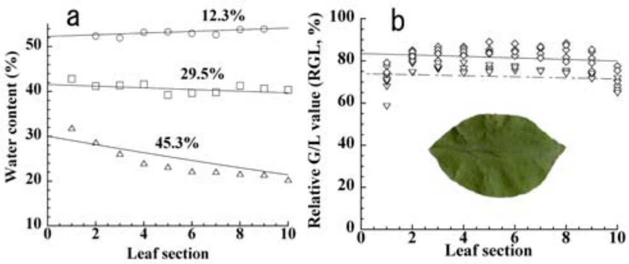

Fig. 5 Responsive curves of water content to the leaf sections with different distances from the leaf proximal (Fig. 5-a, n=5) for detached leaves with different water loss percentages; 12.3% (○–○), 29.5% (□–□) and 45.3% (△–△). It can be seen that detached leaves also dried from distal to proximal especially by the line of 45.3% water loss. The visible image of dried leaf and the responsive curves of *RGL* value for normal leaves (◇–◇) and natural dried detached leaves (▽–▽)(Fig. 5-b).

In general, the structure and function of plants or trees are usually identical. By differential measurement of leaf tip and base of some landscape trees, it showed a tendency that the proximal part accumulated more biomass than that of distal part, which showed a ratio of tip/base less than 1.0, some of them even less than 0.8. This kind of difference should affect the physical and physiological characters of them, although it appears the genetic specific. According to measurement, detached Kousa dogwood leaves showed a tendency gradually dried from distal to proximal (Fig. 5-a). It suggests that there is a faster evapotranspiration speed at leaf tip than at base, which was proved by our half leaf water loss experiment. Meanwhile, the distal part is usually the farthest from water source of them. Therefore, it is not surprise that the phenomenon of leaf tip part of Kousa dogwood dried first was found. No significantly visible variation appeared on the detachedly dried Kousa dogwood leaves and their images (Fig. 5-b). Under this kind of acute water loss situation, there is no time for the leaves to response and no ability to establish the defense barrier as the intact leaves. It also indicates that the defense barrier occurred only on the intact leaves, and the interaction of the leaf dried back and the self-defense response was the key of the TSR of Kousa dogwood. The interaction apparently manifested itself in the fact of species specific and genetic variance. By observation, flower dogwood (*Cornus florida* L.) usually appeared premature red leaf during the extreme summer drought in 2007 and 2008. Only fewer of red leaf florida dogwood trees showed the leaf necrosis after persistent hot and drought stresses and almost no defense barrier had been found on their leaves. However the living part of Kousa dogwood leaves showed persistent green till late autumn. The annual leaf necrosis on Kumazasa bamboo (*Sasa Veitchii* Carr.) in early winter is characterized with leaf chlorosis from tip to proximal firstly, and then necrosis started from the seriously chlorotic leaf tip. Significant defense barrier is usually established on their leaves as the same as the Kousa dogwood. Some flowerbed planted *Datura meteloides* appeared a typical example of response process from chlorosis to leaf shedding, which is different from that of Kousa dogwood and Kumazasa bamboo. Under the persistent water stresses, tip started leaf wilt, and subsequently scroll and chlorosis were shown in turn. The water content of the leaves just starting necrosis at the leaf tip showed a linear decline function from leaf proximal to distal too. However the tip necrotic leaves gradually fell off and no gradually withdrawing defense barriers were found.

Triggering weather condition for TSR of Kousa dogwood

Leaf surface area shearing occurs when water absorption cannot compensate for transpiration losses seriously. It appeared on many Kousa dogwood trees during the abnormal extreme climate in 2007. The meteorological environment in 2007 in Yamaguchi, Japan was characterized by drought and hotness. The annual precipitation was lower and uneven, which was 71.6% of normal year and only 60.1% for the first nine months in 2007. The annual mean temperature in 2007 accounts for 107.3% of the normal year. Particularly, it also made many new records of high temperature and low precipitation during past 41 years (from 1967 to 2007) for Yamaguchi meteorological observatories. The protracted drought led to insufficient soil water supply to plants, especially during sudden hot and droughty days. For example, in May and August in 2007, two peak periods of the AD11 in Yamaguchi from April to August were observed (Fig. 6-a) and consistent well with the period of Kousa dogwood leaf scorch-back. During the first peak period of sudden increasing of the aridity, the accumulative precipitation from April to Jun was only 47.4% of the normal and the precipitation from May 12, 2007 to Jun. 12, 2007 was only 17.6% of total precipitation from April to Jun. In the second peak period, about 15 days of no rain and persistent high temperature and low humidity as well as the high wind speed led to a foehn like weather. Although the precipitation reached a height of making new record of maximum

monthly precipitation in December 2007 in Yamaguchi, it was late for the utilization of plant growing and out of the growing season. Various symptoms appeared on many landscape trees, especially the trees planted on the poor soils and the sites with root growing limitation etc. During the special weather event of high temperature and less precipitation in 2007, large amount of Japanese red pines (*Pinus thunbergii* L.) in mountain area died. Many tree species fell off partial leaves to reduce the transpiring surface. Some *sasanqua camellias* shed all of leaves to evade the extreme hot and droughty environment.

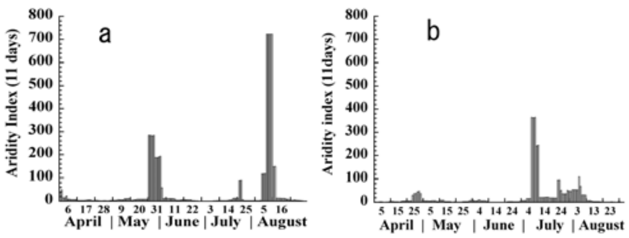

Fig. 6-a gave the 11-day moving average aridity (AD11) from April 1st to the end of August in 2007. It clearly presented two peak periods of AD11, which one occurred during last 10 days in May, and the other during middle ten days in August. Fig. 6-b was the AD11 index from April 1st to the end of August in 2008. It also clearly presented two peak periods. One occurred at the beginning of May and the other from July 4th to August 4th.

In 2008, some newly complementarily planted trees, without perfect root system established, showed the gradually leaf scorch-back symptoms. It also occurred during two sudden hot and dry peak periods (Fig. 6-b). For the normal Kousa dogwood trees no similar leaf scorch-back occurred until August 2th after almost one-month persistent drought and high temperature and it was also consistent well with a persistent peak period of AD11 in 2008 (Fig. 6-b). Although the weather condition and water status of the Kousa dogwood trees varied, almost all of the scorch-back symptoms occurred during the sudden hot and dry period (Fig. 6-a, 6-b) and fewer water supplies in common. The sudden increasing of the aridity under the persistent less water supply condition should be the triggering factor for the leaf scorch-back of the dogwood trees during the dual events of transpiration surface reduction in the years of 2007 and 2008. Therefore it may be usable to spray water on the surface of leaves or deep water the trees before serious drought and hot event occurrence to decrease the extreme water stress and maintain the normality of the transpiring cooler system as well as support more leaf area to dogwood trees.

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